2020 R- 08. Strawberry crop performance following anaerobic soil disinfestation using brewer's spent grain and yeast inoculation

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Public Abstract

BACKGROUND: Anaerobic soil disinfestation (ASD) is a promising alternative to chemical fumigation to control soilborne plant pathogens and weeds. During 2019-2020 strawberry growing season, we initiated an open-field study to evaluate weed pressure, crop nitrogen status and strawberry yield following anaerobic soil disinfestation using brewer's spent grain (BSG), paper mulch (PM), and yeast inoculation in open-field annual hill production. The study was randomized, replicated (four times) with nine treatments. We evaluated BSG + PM with/without distiller`s dry yeast at standard rate (4mg of C/g of soil, 2.7t/ha), half dose rate of BSG+PM with/without distiller's dry yeast. We used nontreated control (no C source) with/without yeast and Pic-Clor80 fumigation (196 kg/ha) as control groups. All BSG + PM treatments received no addition preplant nitrogen fertilizer as the C sources provided, while three nontreated control groups received 105 kg/ha preplant synthetic nitrogen fertilizer. We had two treatments that received extra synthetic fertilizer, which included one standard rate BSG + PM without yeast (54 kg/ha nitrogen fertilizer) and one nontreated control without yeast (159 kg/ha nitrogen fertilizer). Each replicate on-site was 10.7 m long bed with 0.15 m height and 0.7 m wide bed tops. After the ASD, we transplanted strawberry 'Ruby June' at a 3.6 m length and 0.7 m wide planting area at the middle of the bed. Close to the planting area, weed viewing area (1.5 m length and 0.7 wide bed tops) was made by replacing the black tarp with clear tarp. We collected data on strawberry plant health, weed density from weed viewing area, plant biomass and crop yield.

RESULTS: All ASD treatments had significant lower counts of Carolina geranium (36%-69% less), cudweed (41%-67% less) and white clover (48%-68%), total weed count (48%-70% less), wet biomass (49%-62% less) and dry biomass (60%-73%) compared to nontreated control without yeast. All ASD treatments had comparable effect to the Pic-Clor80 on the above counts and biomass. The use of all ASD treatments and Pic-Clor80 significantly increased marketable and total yield compared to nontreated control without yeast. ASD with yeast had comparable marketable and total yield to Pic-Clor80, while ASD without yeast had significantly lower yield than Pic-Clor80. There was no significantly difference in neither fresh nor dry plants biomass among treatments except the fumigant, which had higher fresh biomass for leaves and crowns, and higher dry biomass for leaves, petioles and roots.

CONCLUSION: The ASD treatments (full and half rates) with yeast have potential to provide comparable weed control and yields as fumigation and could reduce the use of synthetic preplant nitrogen fertilizer. The yeast amendments could enhance the yield for ASD treatments, which make it possible to put less C in ASD treatments.

Introduction. Our objective was to evaluate disease and weed pressure, crop nitrogen status and strawberry yield following anaerobic soil disinfestation using brewer's spent grain and yeast inoculation in open-field annual hill production.

Materials and Methods.

During the 2019-2020 growing season, we initiated a randomized, replicated (four times) study with nine treatments in an open-field study at the Hampton Reads AREC in fall 2019. Each replicate on-site was 10.7 m long bed with 0.15 m height and 0.7 m wide bed tops. Treatments on-site are in Table 1.

Table 1. Treatment list including the rates of C sources and nitrogen rate from both C sources and fertilizer.

Treatments:	Yeast (kg/ha)	BSG (t/ha)	Paper mulch (t/ha)	N from C sources (kg/ha)	N from synthetic fertilizer (kg/ha)	Total N (kg/ha)
C sources full						
(i) Without yeast	0	1.41	1.29	105	0	105
(ii) With yeast	10	1.41	1.29	105	0	105
(iii) With extra synthetic fertilizer	0	1.41	1.29	105	54	159
C sources half						
(iv) Without yeast	0	2.51	0.19	105	0	105
(v) With yeast	5	2.51	0.19	105	0	105
Non-treated control						
(vi) Without yeast	0	0	0	0	105	105
(vii) With yeast	10	0	0	0	105	105
(viii) With extra synthetic fertilizer	0	0	0	0	105+54	159
(ix) Pic-Clor80	0	0	0	0	105	105

For the ASD treatments, we broadcasted the C, and covered the C sources with a 1.25 mil-virtually impermeable film and used drip irrigation to saturate the soil. TDR soil moisture meter with probes was used periodically over three weeks to estimate saturation of field soil. The C at 4 and 2 mg /g of soil provided 105 kg/ha of nitrogen. These treatments received no additional preplant fertilizer. Preplant nitrogen for all other treatments were matched to 105 kg N/ha by the addition of synthetic N fertilizer. No phosphorus or potassium was needed as per the soil test. Treatments iii and viii had nontreated control and brewer's spent grain (4 mg of C/g of soil) with fertilizer dosage recommended by Virginia Tech soil testing laboratory at 54 kg N/ha. ASD treatment was initiated on 5 Sept. 2019 and terminated on 27 Sept. 2019. Planting holes were made on 27 Sept. 2019 and 16 'Ruby June' plants per replicate were transplanted on 10 Oct.

2019 in two rows per bed spaced 14 inches apart in a staggered manner. Strawberry plots were maintained as per standard grower recommendations. We recorded data on strawberry plant health, disease incidence, weed density and crop yield.

Temperature and Redox potential data. Sensors were programmed to collect data every 10 min. during the treatment period. We calculated the cumulative Redox potential values (Eh) below a critical redox potential determined to indicate anaerobic conditions (~ 200 mV). The absolute value of the difference between a given Eh and critical redox potential (CEh) was summed over the three-week ASD treatment period to give a measure of cumulative soil anaerobic activity. We determined the highest and lowest point temperatures reached during the three-week ASD period. We also calculated the average temperature during the treatment period for each treatment.

Weed evaluation. We evaluated weed control effectiveness of treatments by counting weed density and recording weed shoot and root biomass in a 1.5 m length by 0.7 m. wide weed viewing window. This viewing window allowed us to separate the treatment effect from the suppressive effects of black plastic film. For weed density, we counted all weed species in the weed window. After each weed count, we harvested the weeds by hand, and recorded the weed biomass of the harvested weeds for each replicate. Weed data were collected on 6 Jan., 19 Feb., and 31 Mar., 2020. Predominant weeds observed during the season were Carolina geranium (*Geranium carolinianum L.*), white clover (*Trifolium repens L.*) and cudweed (*Gnaphalium spp.*).

Yield and post-harvest data. We harvested fruits starting 10 April 2020 up until 15 June 2020. Fruit picking was done by hand twice a week and the harvested fruits were sorted into marketable and nonmarketable categories. The nonmarketable fruits were fruits that were small (<10 g), diseased, rotten, animal bitten, or misshapen. Post-harvest data parameters included collecting fruit size by measuring fruit diameter and fruit firmness. Fruit diameter was collected on 5 marketable fruits collected randomly from each replicate once a week and fruit diameter were recorded using Vernier caliper scale. We checked the firmness of fruit using a tabletop fruit texture analyzer (GS-15 Fruit Texture Analyzer, QA Supplies, Norfolk, VA). At every other harvest period, five fruits from each replicate were randomly tested for firmness. After that, the same five fruits were tested for total soluble solids using refractometer (MA871 Refractometer, Milwaukee, Rocky Mount, NC), and were tested for pH using pH tester (combo pH/conductivity/TDS tester, HANNA Instruments, Smithfield, RI). After the harvest season, we picked 6 plants per plot for biomass analysis on 23 June 2020 and 24 June 2020. Each plant was divided into six parts, which included leaves, petioles, crown, root, flower and berries. We recorded both fresh weight and dry weight of all six parts.

Data analysis. We analyzed the data using JMP v. 14 (SAS Institute Inc., Cary, NC, USA). We checked the data for normality and homogeneity of variance assumptions. We looked at the treatment effect. The data were analyzed by one-way analysis of variance (ANOVA), comparing the means of the treatments by Fisher's least significant difference (LSD) at alpha = 0.05.

Results. All ASD and Pic-Clor80 treatments had significantly lower counts of cudweed, white clover, total weed count, wet and dry biomass comparing to nontreated control without yeast (Table 2). ASD treatments had a comparable effect on weed control to the Pic-Clor80 treatment. For Carolina geranium, only the ASD with yeast treatments had significantly lower density than the nontreated control and Pic-Clor80. Moreover, ASD using C sources full rate with yeast had better performance than Pic-Clor80 on Carolina geranium and white clover control. For white clover, ASD using full rate C sources and nontreated control had significantly lower counts when yeast was added than without yeast.

The use of all ASD treatments and Pic-Clor80 provided significantly higher cumulative marketable and total yield for the whole harvest season compared to nontreated control without yeast (Table 3). ASD with yeast had comparable total marketable and total yield to Pic-Clor80, while ASD without yeast had significantly lower yield than Pic-Clor80. Thus, the yeast amendments significantly enhanced the marketable and total yield for ASD treatments. Similar trends were also found in April, May and June during the harvest season. There were no significant differences in fresh nor dry biomass among treatments except the fumigant. The fumigant treatment had significantly higher fresh biomass for strawberry leaves and crowns, and higher dry biomass for leaves, petioles and roots (data not shown).

Fruit size, fruit firmness and pH of the fruit were not significantly different among treatments (data not shown). For the total soluble solids (Table 3), the ASD using full rate C sources with yeast, ASD using half-rate with and without yeast, and nontreated control with yeast and with extra fertilizer all had significantly higher Brix readings than Pic-Clor80.

Outreach. Findings from this study were presented at the NCCC 212: Small Fruit and Viticulture Research meeting. Further outreach of this work will be done in meetings in 2021.

Table 2. Cumulative weed count and weed biomass for 5-linear-feet length window after anaerobic soil disinfestation (ASD) process with several different C dose rates and yeast amendment.

	Weed count[b]				Wet biomass(g)[b]	Dry biomass(g)[b]
Treatment[a]	Carolina geranium	Cudweed	White Clover	Total		
C sources full						
Without yeast	15 cde	6.6 b	34.25 c	68 bc	919 b	604 b
With yeast	10 e	8 b	20.75 d	44 c	761 b	449 b
With extra synthetic fertilizer	13 de	7 b	26.5 cd	60 bc	888 b	562 b
C sources half						
Without yeast	21 bcd	4.5 b	29.5 cd	76 b	1021 b	652 b
With yeast	13 cde	6.5 b	28.5 cd	57 bc	955 b	615 b
Non-treated control						
Without yeast	33 a	13.75 a	66.5 a	148 a	2006 a	1667 a
With yeast	23 abc	18.25 a	53 b	135 a	1642 a	1318 a
With extra synthetic fertilizer	29 ab	16.25 a	58.75 ab	150 a	1774 a	1446 a
Pic-Clor80	21 bcd	8 b	34.25 c	67 bc	1008 b	657 b
P-value	0.0012	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a] The rates of C sources and yeast were as follows: C sources full rate 4 mg C/g soil, 2.7 t/ha, yeast full rate 10 kg/ha, C sources half rate 2mg C/g soil, 1.35 t/ha, yeast half rate 5 kg/ha, non-treated control with yeast 10 kg/ha. The extra fertilizer was 54 kg/ha. Pic-Clor80 fumigated at 196 kg/ha

[b] Means followed by different letters within a column are statistically different basing on Wilcoxon test at $P \leq 0.05$.

Table 3. Mean, min and max temperature for 3-weeks period anaerobic soil disinfestation (ASD) process with several different C dose rates and yeast amendment.

Treatment[a]	Cumulative yield (g/plant)[b]		April yield (g/plant)[b]		May yield (g/plant)[b]		June yield (g/plant)[b]		Total soluble solids (°Bx)[b]
	Marketable[c]	Total[c]	Marketable	Total	Marketable	Total	Marketable	Total	
C sources full									
Without yeast	382 bc	392 bc	64.8 abc	65.3 abc	210.7 bc	213.1 bc	106.5 bc	114.1 b	7.76 bcd
With yeast	630 a	643 a	110.0 a	110.0 a	350.3 a	354.3 a	170.2 a	179.2 a	8.17 ab
With synthetic fertilizer	394 b	413 b	71.5 abc	71.5 abc	225.5 bc	230.4 bc	96.5 cd	110.7 bc	7.88 bcd
C sources half									
Without yeast	383 bc	395 bc	56.5 bc	56.5 bc	222.3 bc	222.3 bc	104.8 cd	110.4 bc	7.99 abc
With yeast	534 a	548 a	86.5 ab	86.5 ab	292.0 ab	298.5 ab	156.1 a	162.8 a	8.11 abc
Non-treated control									
Without yeast	219 d	235 d	29.0 c	29.9 c	138.3 c	146.7 c	52.0 e	58.2 d	7.51 cd
With yeast	272 cd	280 cd	38.0 c	38.9 c	168.4 c	174.7 c	66.1 de	66.6 cd	7.91 bc
With synthetic fertilizer	279 bcd	299 bcd	44.6 bc	44.6 bc	164.5 c	177.7 c	70.0 cde	76.3 bcd	8.56 a
Pic-Clor80	531 a	597 a	63.4 bc	70.2 abc	323.0 a	353.7 a	144.4 ab	173.0 a	7.25 d
P-value	<0.0001	<0.0001	0.0346	0.0397	0.00002	<0.0001	<0.0001	<0.0001	0.0177

[a] The rates of C sources and yeast were as follows: C sources full rate 4 mg C/g soil, 2.7 t/ha, yeast full rate 10 kg/ha, C sources half rate 2mg C/g soil, 1.35 t/ha, yeast half rate 5 kg/ha, non-treated control with yeast 10 kg/ha. The extra fertilizer was 54 kg/ha. Pic-Clor80 fumigated at 196 kg/ha
[b] Means followed by different letters within a column are statistically different using Fisher`s LSD test at $P \leq 0.05$.
[c] Harvested fruits were graded into marketable (fresh market grade) and nonmarketable(culls). Total yield was the sum of marketable and nonmarketable yields. The marketable consist of strawberries which are firm, at least 10 g, not overripe or overdeveloped, and which are free from mold or decay, and free from damage caused by mechanical or biotic factors.